Emerging wastewater contaminants in Cape Cod drinking water

Laurel Schaider, Ph.D.
Research Scientist
Silent Spring Institute, Newton, MA

NHDES Drinking Water Source Protection Conference
6 May 2015

Science on msnbc.com

Study: Male bass in many U.S. rivers feminized

Intersex fish linked to birth control pills, other hormones seeping into rivers

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Dayton Daily News

Testing reveals low levels of drugs in drinking water source

Agencies discourage flushing of prescriptions

THE TENNESSEAN

Chemicals on tap demand caution

Consumers can do most to contain questionable substances in water

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At the Orange County Sanitation District, a settling basin is used to filter water as part of the advanced secondary treatment, before the water is diverted into the ocean, in Fountain Valley, Calif. Pharmaceuticals in waterways are damaging wildlife across the nation and around the globe, research shows.

By Ric Francis, AP

AP: Drugs found in drinking water

Updated 9/12/2008 2:02 PM | Comments 149 | Recommend 83

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By Jeff Donn, Martha Mendoza and Justin Pritchard, Associated Press

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What's this?

A vast array of pharmaceuticals — including antibiotics, anti-convulsants, mood stabilizers and sex hormones — have been found in the drinking water supplies of at least 41 million Americans, an Associated Press investigation shows.

To be sure, the concentrations of these pharmaceuticals are tiny, measured in quantities of parts per billion or trillion, far below the levels of a medical dose. Also, utilities insist their water is safe.

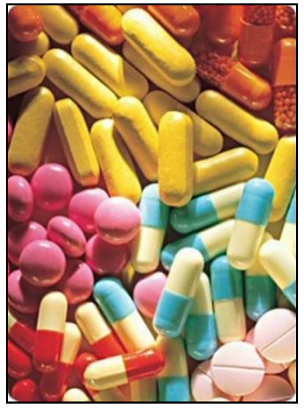
WATER DEPARTMENTS: Reports rarely released to public
BOTTLED WATER: Is it any safer?
NEW YORK CITY: Sedative traces found in water
LOS ANGELES: Water tops national taste test
RELATED: Problems in fish blamed on contamination

But the presence of so many prescription drugs — and over-the-counter medicines like acetaminophen and ibuprofen — in so much of our drinking water is heightening worries among scientists of long-term consequences to human health.

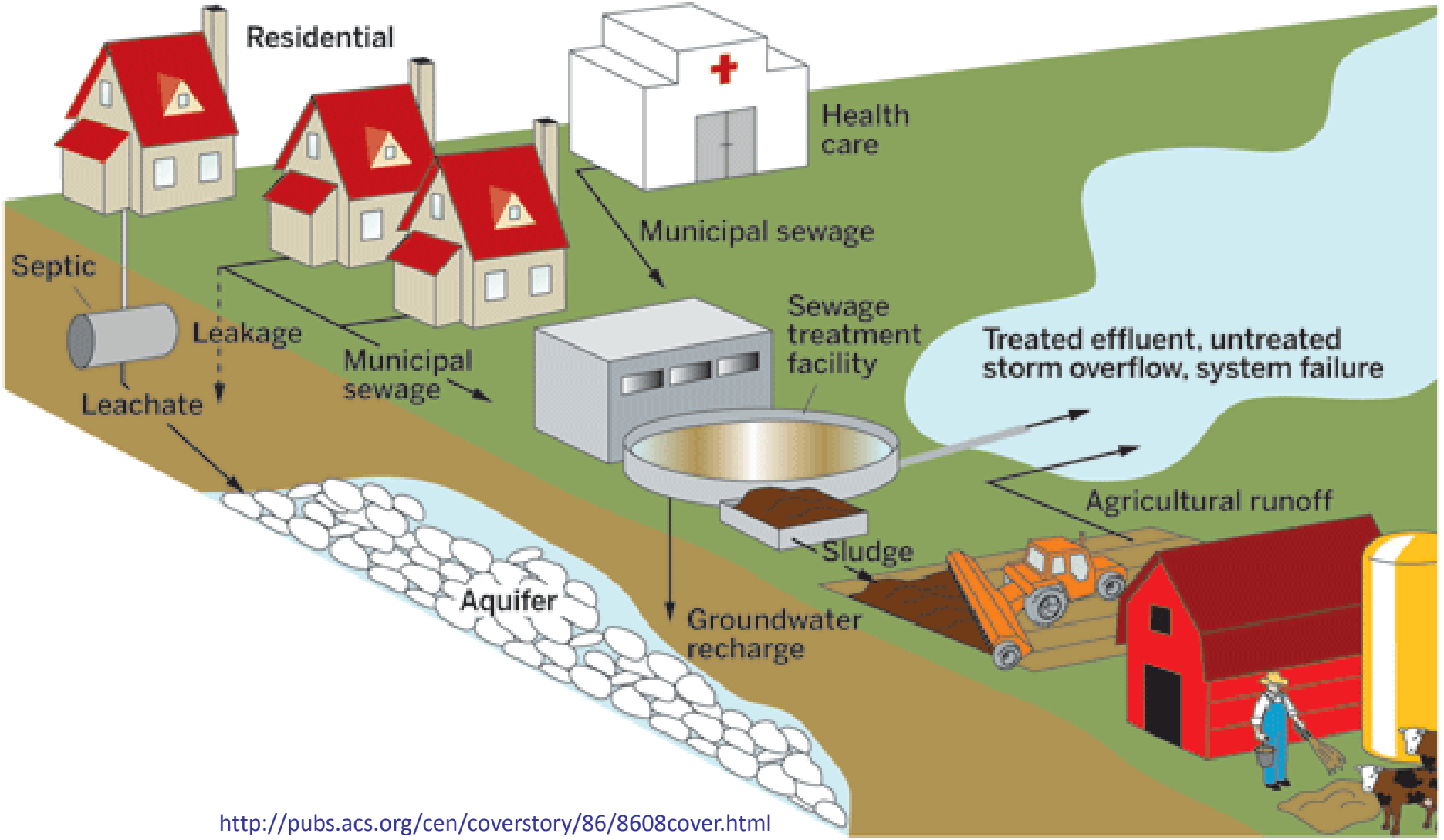
http://www.b12partners.net/wp/wp-content/uploads/2008/05/mike_keefe_water.jpg

Emerging Contaminants
or Contaminants of Emerging Concern, or Organic Wastewater Contaminants

- Examples: Pharmaceuticals and personal care products (PPCPs), hormones, perfluorinated chemicals, flame retardants
- Not currently regulated in drinking water, some are candidates (CCL3, UCMR3)
- Frequently detected in surface water, groundwater, and drinking water
- Ecological concerns, especially endocrine disruption, and human health concerns



How do emerging contaminants get into the environment?



http://pubs.acs.org/cen/coverstory/86/8608cover.html

How do emerging contaminants get into Cape Cod groundwater?

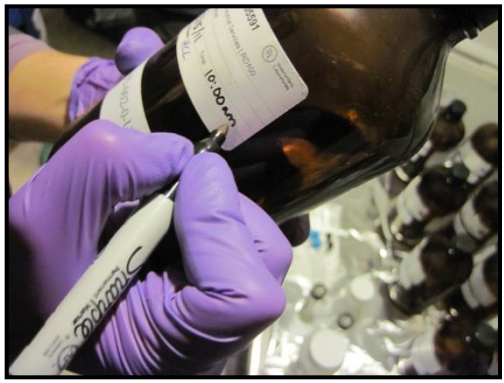
http://pubs.acs.org/cen/coverstory/86/8608cover.html

Cape Cod drinking water supplies are vulnerable

- 85% of homes have septic systems
- Sand and gravel sole source aquifer
- Rapid development

Silent Spring Institute water quality research

- Measure endocrine disruptors and other emerging contaminants in drinking water, groundwater, ponds
- Evaluate septic systems as sources of contaminants and characterize subsurface transport
- Inform Cape wastewater management and drinking water protection decision-making



Silent Spring Institute
Cape Cod water research

Septic systems

- First study to identify estrogen mimics in household wastewater and groundwater
- Comprehensive survey of OWCs from septic systems and comparisons to sewage treatment plant discharges

Environ. Sci. Technol. **1998**, *32*, 861–869

Identification of Alkylphenols and Other Estrogenic Phenolic Compounds in Wastewater, Septage, and Groundwater on Cape Cod, Massachusetts

RUTHANN A. RUDEL,*,† STEVEN J. MELLY,† PAUL W. GENO,‡ GANG SUN,‡ AND JULIA G. BRODY†

Silent Spring Institute, 29 Crafts Street, Newton, Massachusetts 02158, and Southwest Research Institute, 6220 Culebra Road, San Antonio, Texas 78228-0510

Silent Spring Institute
Cape Cod water research

Septic systems

Groundwater

Environ. Sci. Technol. **2006**, *40*, 4894–4902

Steroid Estrogens, Nonylphenol Ethoxylate Metabolites, and Other Wastewater Contaminants in Groundwater Affected by a Residential Septic System on Cape Cod, MA

CHRISTOPHER H. SWARTZ,*,†,‡ SHARANYA REDDY,§ MARK J. BENOTTI,§ HAIFEI YIN,§ LARRY B. BARBER,⊥ BRUCE J. BROWNAWELL,§ AND RUTHANN A. RUDEL†

- Some hormone disruptors and other OWCs are persistent in groundwater
- Persistence of OWCs depends on dissolved oxygen levels

Environmental Toxicology and Chemistry, Vol. 27, No. 12, pp. 2457–2468, 2008

WASTEWATER-CONTAMINATED GROUNDWATER AS A SOURCE OF ENDOGENOUS HORMONES AND PHARMACEUTICALS TO SURFACE WATER ECOSYSTEMS

LAUREL J. STANDLEY,*† RUTHANN A. RUDEL,† CHRISTOPHER H. SWARTZ,‡ KATHLEEN R. ATTFIELD,†
JEFF CHRISTIAN,§ MIKE ERICKSON,§ and JULIA G. BRODY†
†Silent Spring Institute, 29 Crafts Street, Suite 150, Newton, Massachusetts 02458, USA
‡Stockholm Environment Institute, 11 Curtis Avenue, Somerville, Massachusetts 02144, USA
§Columbia Analytical Services, 1317 South 13th Avenue, Kelso, Washington 98626, USA

Septic systems

Groundwater

Ponds more impacted by residential development have more hormones and pharmaceuticals

Ponds

Today's presentation

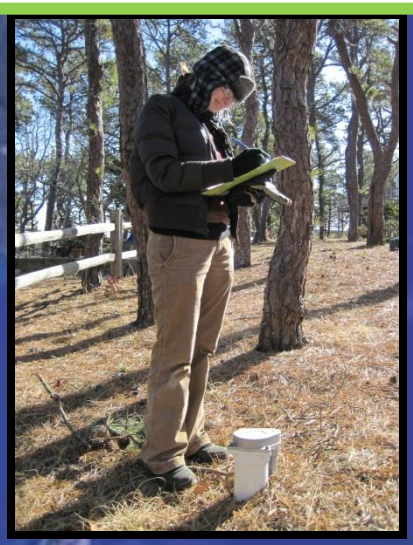
Septic systems

Groundwater

Ponds

Public wells

Private wells



Drinking water study objectives

- Measure OWCs in Cape Cod public and private drinking water wells
- Compare results to other U.S. drinking water sources and to health-based guideline values
- Determine whether land use and chemical wastewater markers are predictors of OWCs
- Inform local discussion of wastewater management and drinking water protection

Chemical analyses

- Raw water tested for ~100 OWCs
  - PPCPs (pharmaceuticals, fragrances)
  - Hormones (synthetic and endogenous)
  - Perfluorinated chemicals (e.g., PFOS, PFOA)
  - Alkylphenols and AP ethoxylates
  - Herbicides
  - Organophosphate flame retardants (e.g., TCEP, TDCPP)

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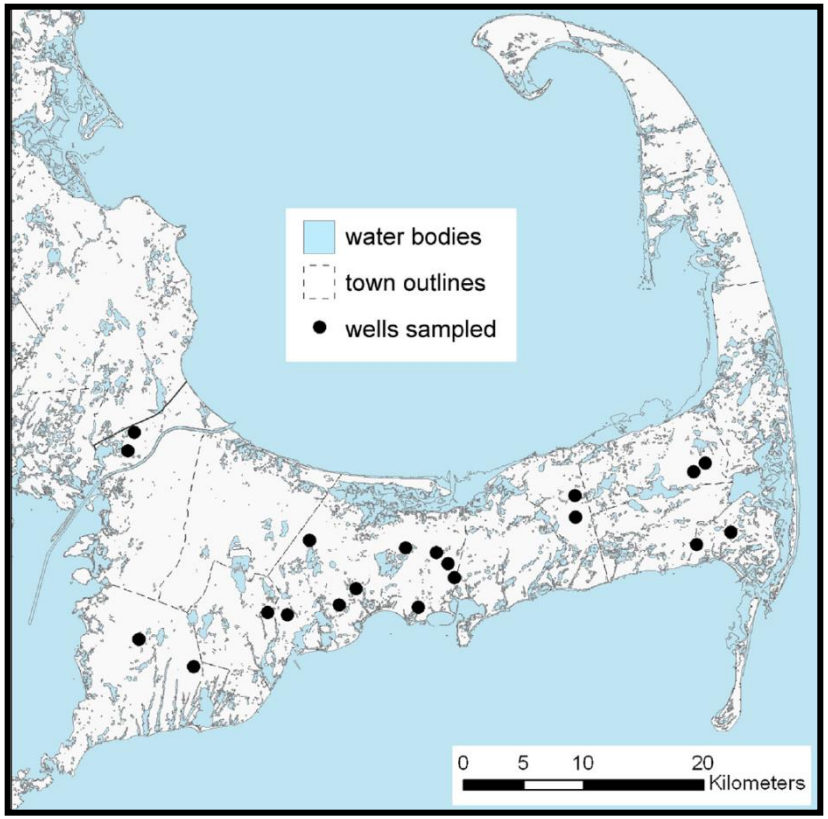
  - Organophosphate flame retardants (e.g., TCEP, TDCPP)
- QA/QC samples (blanks, matrix spike, duplicates)
- Methods: SPE followed by LC/MS/MS or GC/MS
- Analyses conducted by Underwriters Laboratories

Public wells study

- Collected October 2009
- 20 wells in 9 water districts
- Wastewater impact assessed using recent nitrate (NO_3^-) and extent of development in recharge areas
- Range of pollution impact
  - [NO_3^-]: <0.1 to 5.3 mg/L
  - Median [NO_3^-]: 1 mg/L
  - Median for 9 districts: 0.7 mg/L

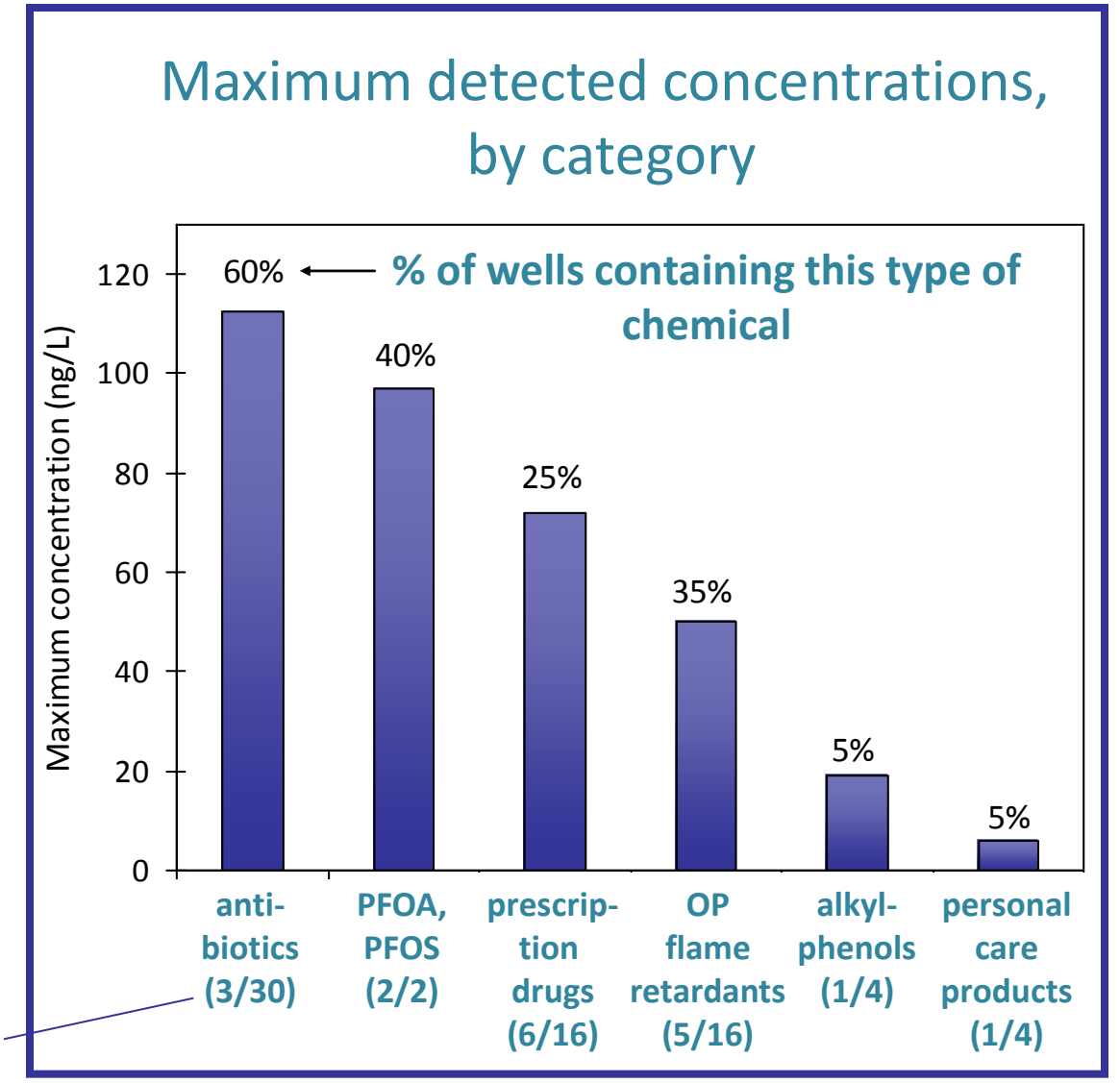


Schaider et al. 2014. *Sci Tot Env*. 468-9:384-93.

Results: OWCs in public wells

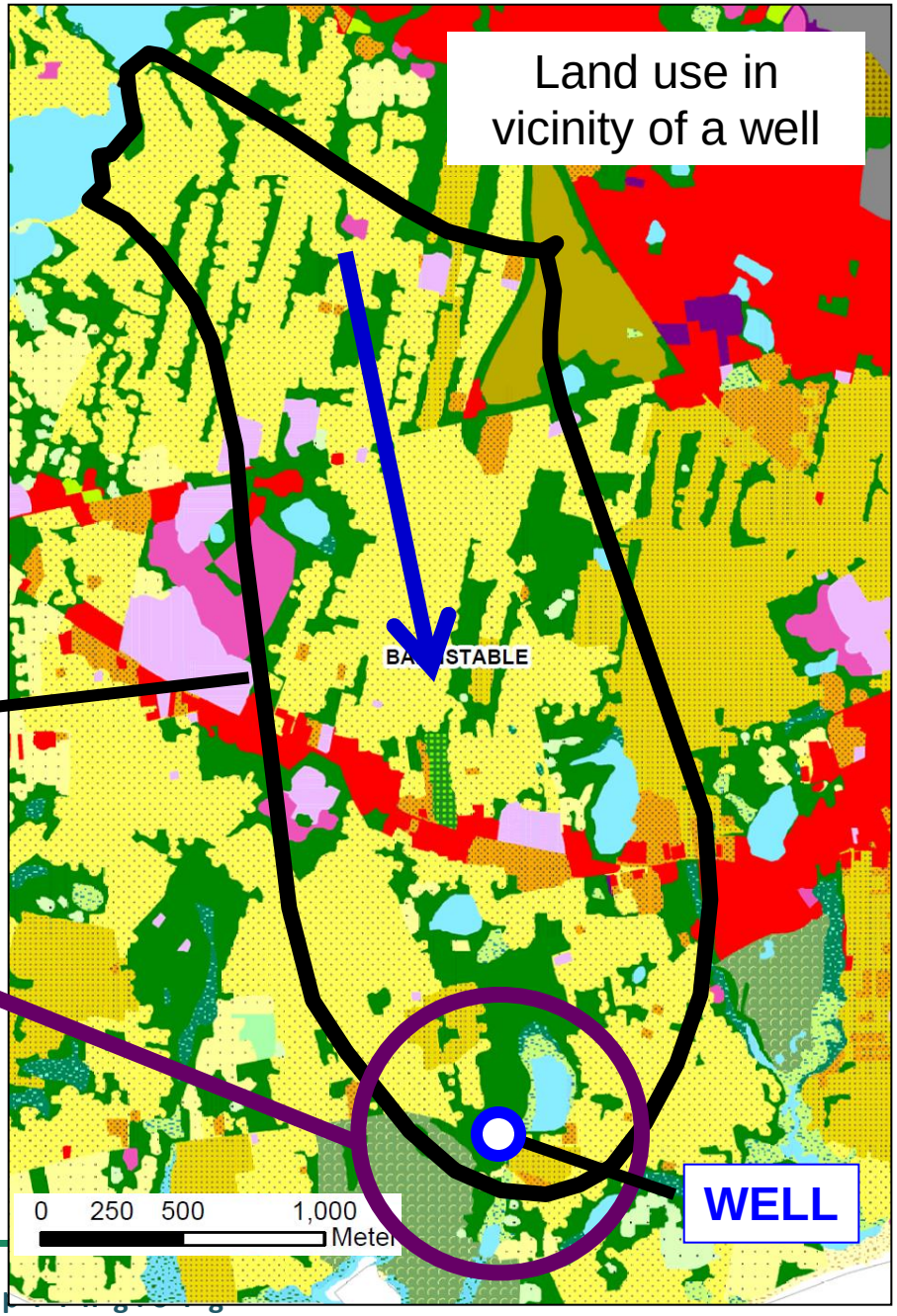
- 18 OWCs detected
- OWCs detected in 15 of 20 wells
- 0–12 OWCs per well
- Most frequently detected:
  - Sulfamethoxazole *(antibiotic)*
  - PFOS *(perfluorinated chemical)*

For each category,
(number detected / number tested)



Predictors of OWCs

- Nitrate
- Boron
- Well depth
- Unsewered development
  - Zone of contribution
  - 500-m zone



Example land use types

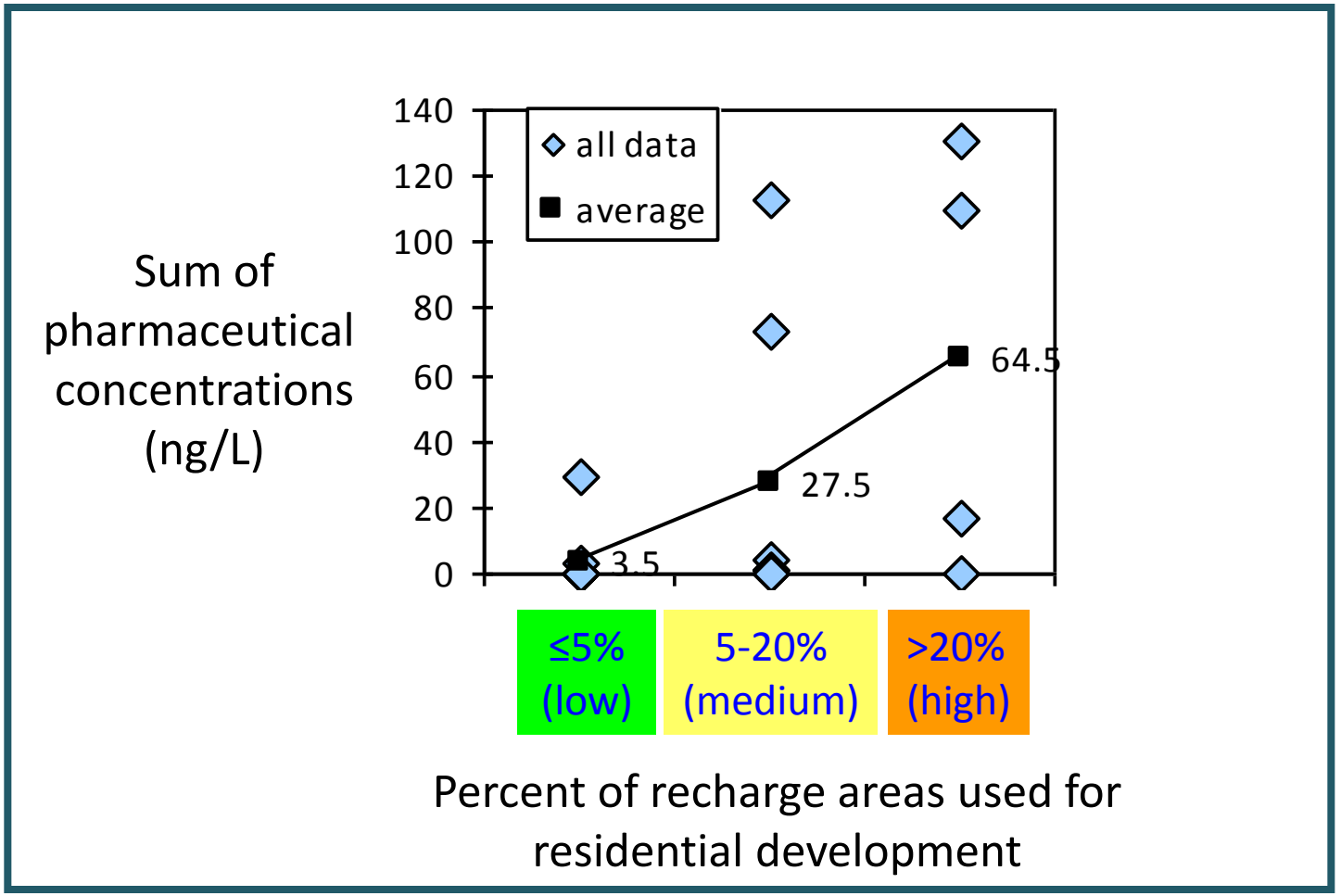
Residential

Commercial

Industrial

Forest & open land

Wells with more residential development had more emerging contaminants



Predictors of OWCs detected

Spearman correlation coefficients

	nitrate	boron
Σ[pharmas]	0.77***	0.63**
# of detects	0.71***	0.73***

• p<0.1, * p<0.05, ** p<0.01, *** p<0.001

Schaider et al. 2014. *Sci Tot Env*. 468-9:384-93.

Predictors of OWCs detected

Spearman correlation coefficients

	nitrate	boron	%DEV in zone of contrib.	%DEV within 500m
Σ[pharmas]	**0.77*** **	**0.63** **	0.43·	**0.67** **
# of detects	**0.71*** **	**0.73*** **	0.32	**0.52***

· p<0.1, * p<0.05, ** p<0.01, *** p<0.001

Schaider et al. 2014. *Sci Tot Env*. 468-9:384-93.

N, B and %DEV within 500m all correlated with Σ[pharmas] and with number of detects.

Predictors of OWCs detected

Spearman correlation coefficients

	nitrate	boron	%DEV in zone of contrib.	%DEV within 500m	well depth
Σ[pharmas]	**0.77*** **	**0.63** **	0.43·	**0.67** **	-0.33
# of detects	**0.71*** **	**0.73*** **	0.32	**0.52***	-0.26

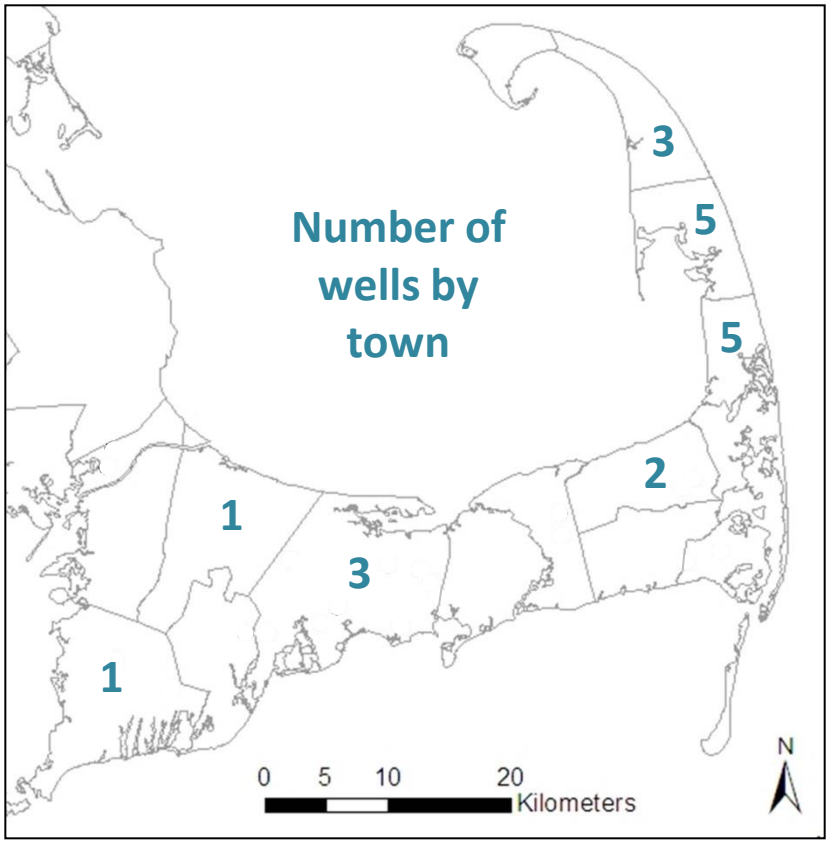
· p<0.1, * p<0.05, ** p<0.01, *** p<0.001

Schaider et al. 2014. *Sci Tot Env*. 468-9:384-93.

N, B and %DEV within 500m all correlated with Σ[pharmas] and with number of detects.

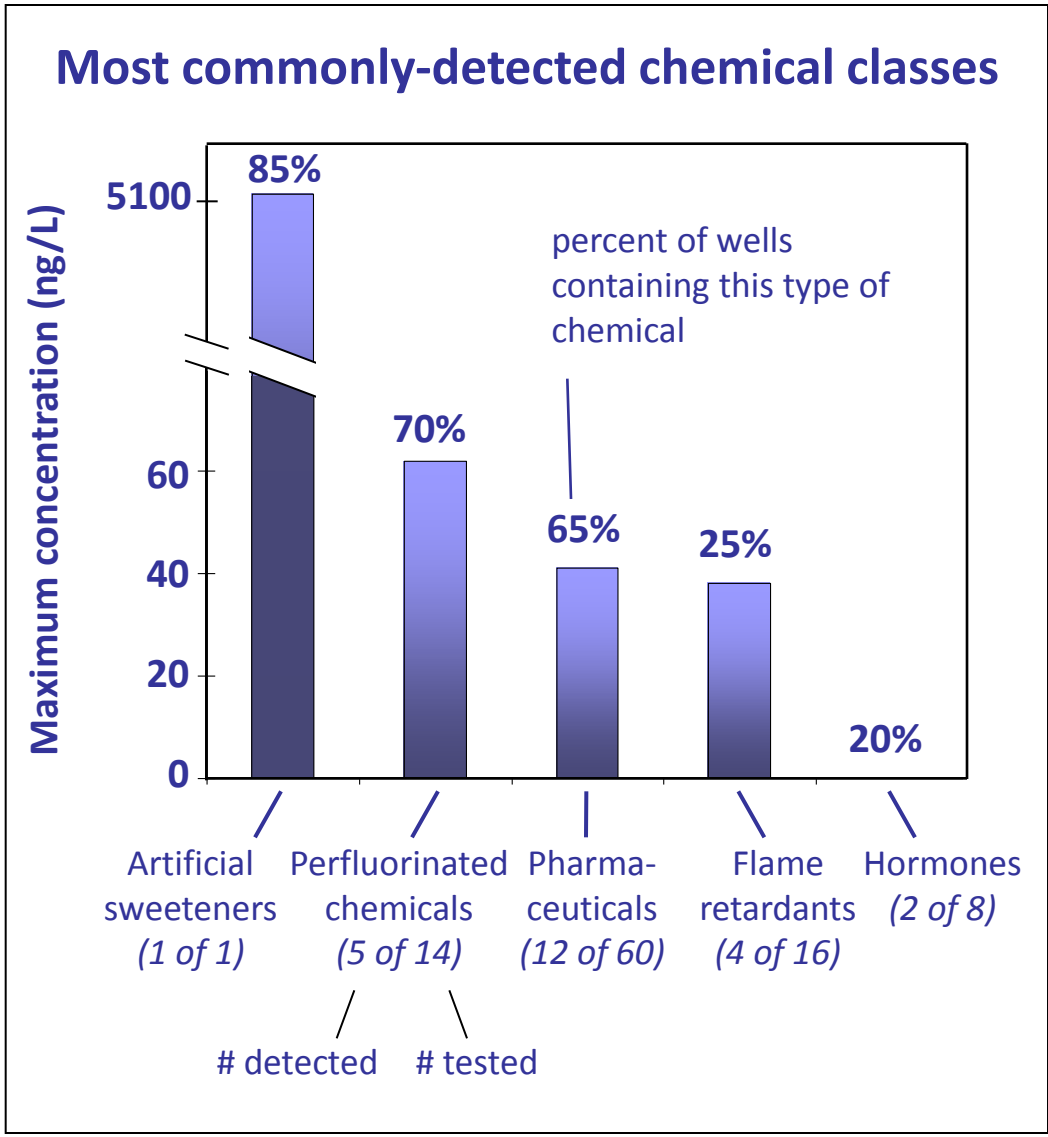
Private drinking water wells

- Raw water from 20 private wells
- Collected February 2011
- Included a range of locations and likely impacts, emphasized moderately and highly impacted wells
  - [NO_3^-]: <0.1 to 11 mg/L
  - Median [NO_3^-]: 2.3 mg/L



Results: Private wells

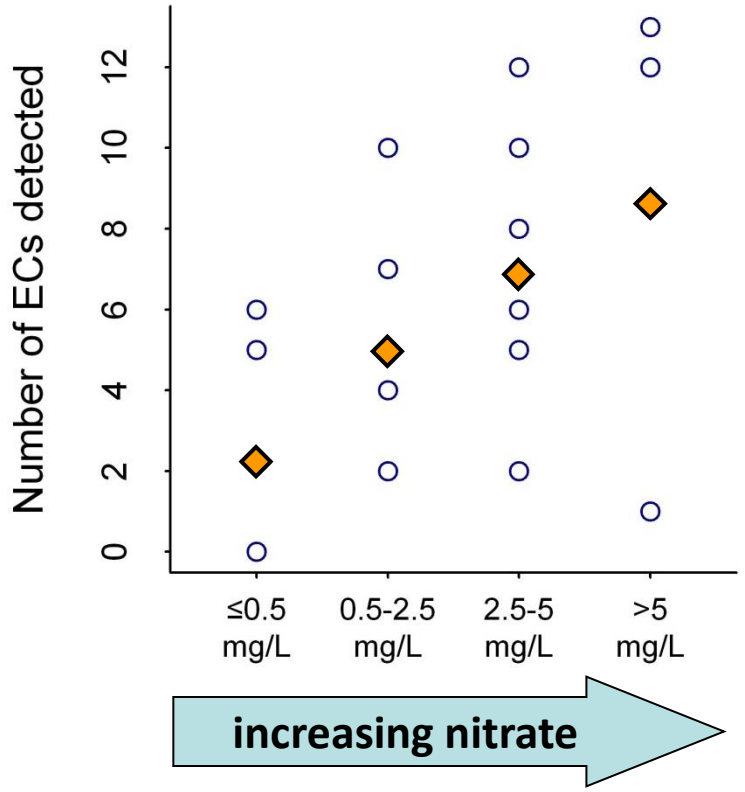
- 85% of wells with ≥ 1 OWC
- 27 of 121 OWCs detected at least once
- 0–13 chemicals per well
- Most frequently detected:
  - Acesulfame *(artificial sweetener)*
  - 4 perfluorinated chemicals (PFOS, PFBS, PFHxS, PFHxA)



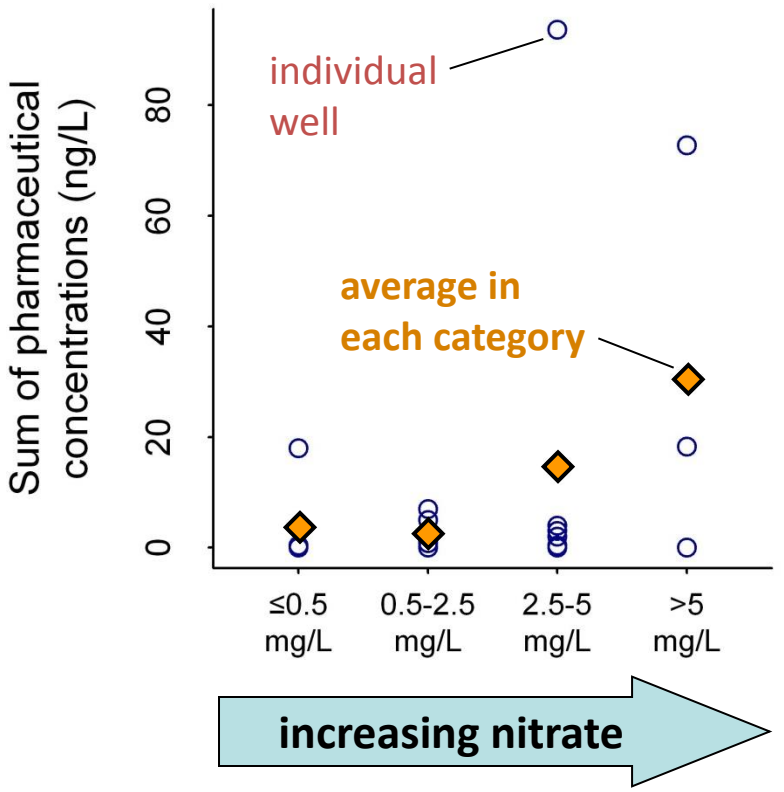
Schaider et al. 2011.

Wells with higher nitrate levels had...

... more emerging contaminants



... higher pharmaceutical concentrations



Number of detected emerging contaminants and total pharmaceutical concentrations

Spearman correlation coefficients

	nitrate	boron
Σ[pharmas]	0.34	**0.59****
$n_{detects}$	**0.56****	**0.81*****

- p<0.1, * p<0.05, ** p<0.01, *** p<0.001

Number of detected emerging contaminants and total pharmaceutical concentrations

Spearman correlation coefficients

	nitrate	boron	% RES	ace-sulfame
Σ[pharmas]	0.34	**0.59****	0.43•	**0.69*****
$n_{detects}$	**0.56****	**0.81*****	**0.48***	**0.88*****

• p<0.1, * p<0.05, ** p<0.01, *** p<0.001

Acesulfame and boron most strongly correlated with Σ[pharmas] and number of detects.

Number of detected emerging contaminants and total pharmaceutical concentrations

Spearman correlation coefficients

	nitrate	boron	% RES	ace-sulfame	well depth
Σ[pharmas]	0.34	**0.59****	0.43•	**0.69*****	-0.37
$n_{detects}$	**0.56****	**0.81*****	**0.48***	**0.88*****	-0.39

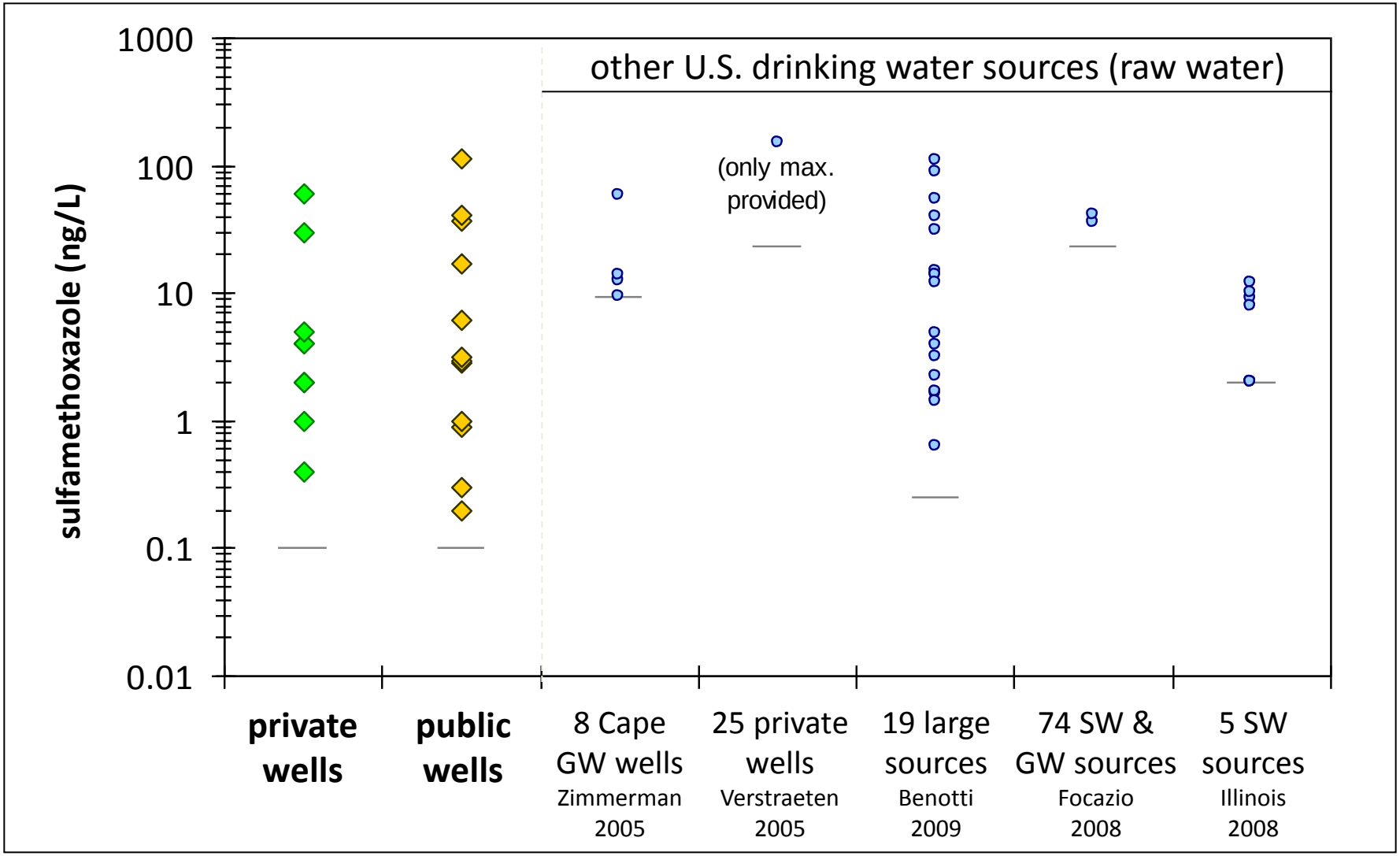
• p<0.1, * p<0.05, ** p<0.01, *** p<0.001

Acesulfame and boron most strongly correlated with Σ[pharmas] and number of detects.

Comparisons to public wells

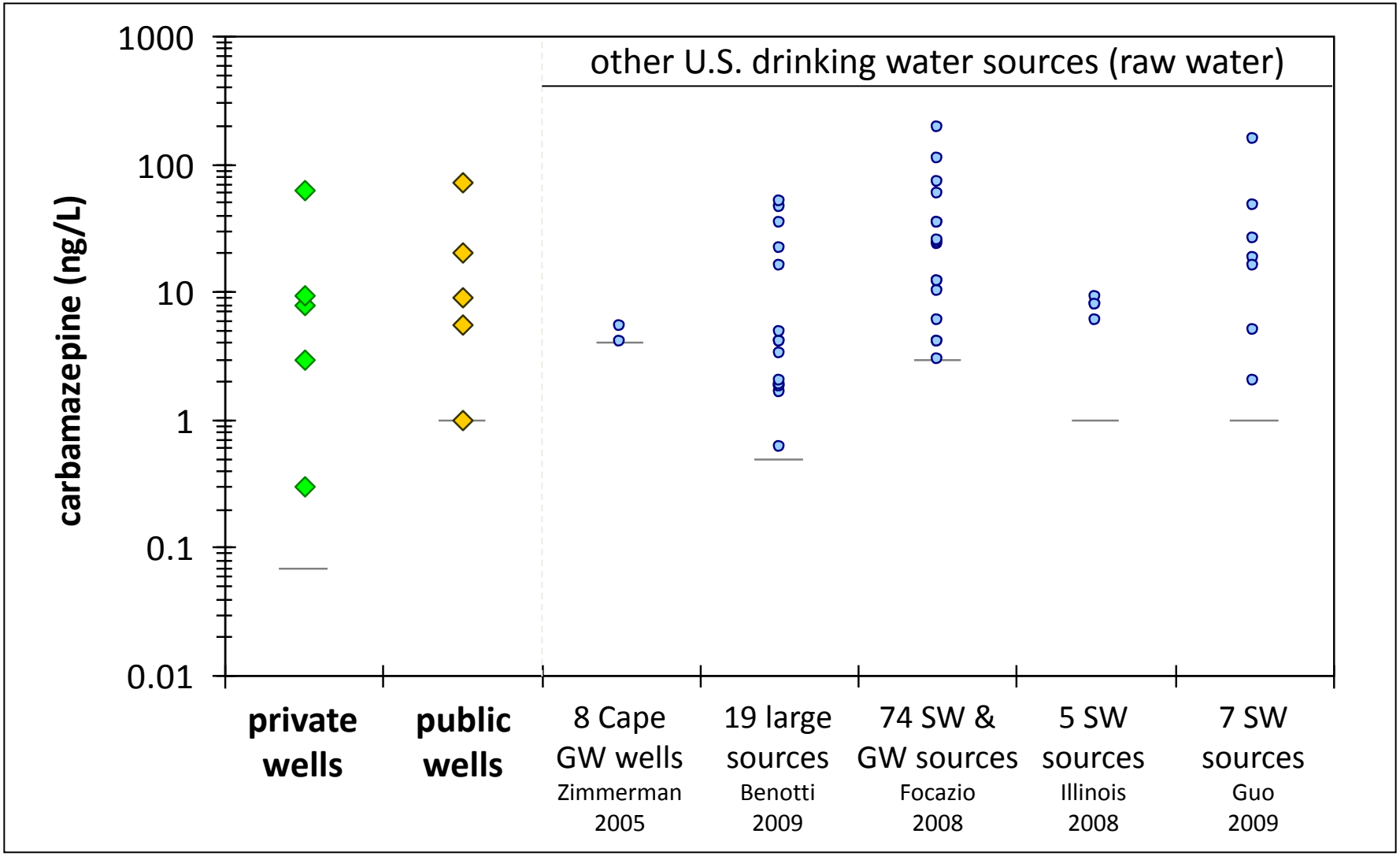
- Results were generally similar for chemicals tested in both
- 4 most common chemicals in public wells were also found in private wells:
  - sulfamethoxazole
  - PFOS
  - carbamazepine
  - TEP (flame retardant)
- Some chemicals only found in public or private wells

Sulfamethoxazole (antibiotic)



GW = groundwater, SW = surface water, —= MRL, DL, or lowest value reported

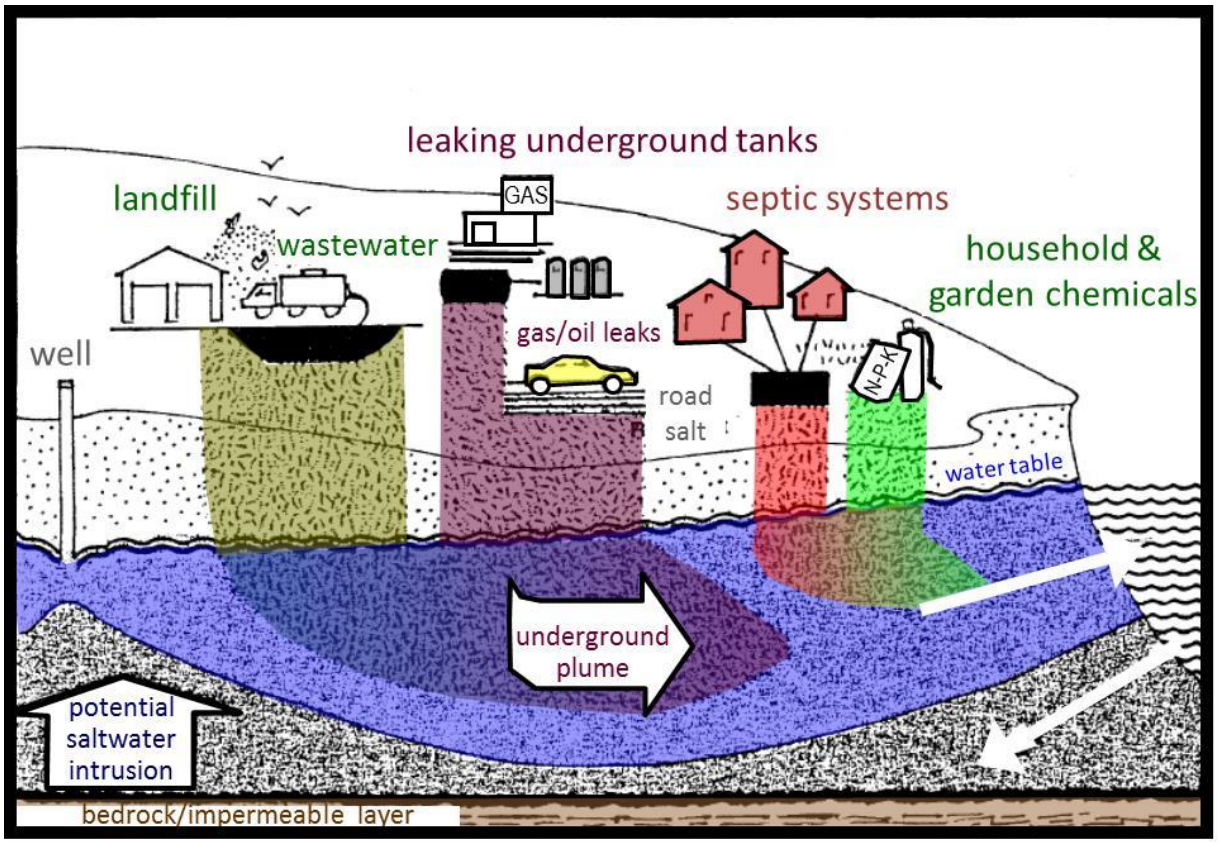
Carbamazepine (antiepileptic)



GW = groundwater, SW = surface water, —= MRL, DL, or lowest value reported

Septic systems are likely main source, but other sources contribute

- Wastewater treatment plant effluent
- Fire fighting foams, aviation-related sources
- Runoff
- Landfills



Adapted from http://www.capecodgroundwater.org/groundwateredpage/groundwater.pdf

Putting it all together: Weighing effects of low-dose exposure

Magnitude of exposures (what is a part per trillion?)

- Pharmaceuticals in drinking water << therapeutic doses
- Exposures through product usage may be much higher
- Current drinking water regulations in µg/L not ng/L

Nevertheless, OWCs in drinking water do raise concerns

- Drugs are potent, intended for specific conditions, and can have side effects
- Regulations do not consider low-dose endocrine disruption
- Potential synergistic effects of chemical mixtures

Communicating results: What can I do?

- Learn where your water comes from, get private wells tested, and consider water filtration
  - Solid carbon block filters can be effective
- Prevent chemicals from getting into wastewater
  - Don’t flush unused medications or hazardous materials
  - Reduce use of products containing harmful chemicals
  - Maintain septic systems
- Support local efforts to protect groundwater
  - Prevent wastewater discharges near wells

Communicating results: Report-back for well owners

For chemicals with guideline values or standards:

Nitrate

Nitrate concentration in your water sample	US EPA's Maximum Contaminant Level
3.5 mg/L	10 mg/L

US EPA's drinking water standard, called the Maximum Contaminant Level, is the highest concentration of nitrate that the US EPA allows in public drinking water supplies.

The Cape Cod Commission's guideline value is designed to provide a margin of safety to keep nitrate below the maximum contaminant level during times of low rainfall or high population.

What do the colors mean?

- Above US EPA's drinking water standard
- Above Cape Cod Commission's guideline value (5 mg/L)
- Above levels that occur naturally
- Within range of levels that occur naturally

The nitrate concentration in your water sample was 3.5 mg/L, which is above the level that occurs naturally in Cape Cod groundwater. Groundwater with nitrate levels above 2.5 mg/L is considered clearly impacted. Elevated nitrate levels can be caused by septic systems or other wastewater sources, fertilizers used for agriculture or landscaping, or other human activity.

Communicating results: Report-back for well owners

For chemicals without guideline values or standards:

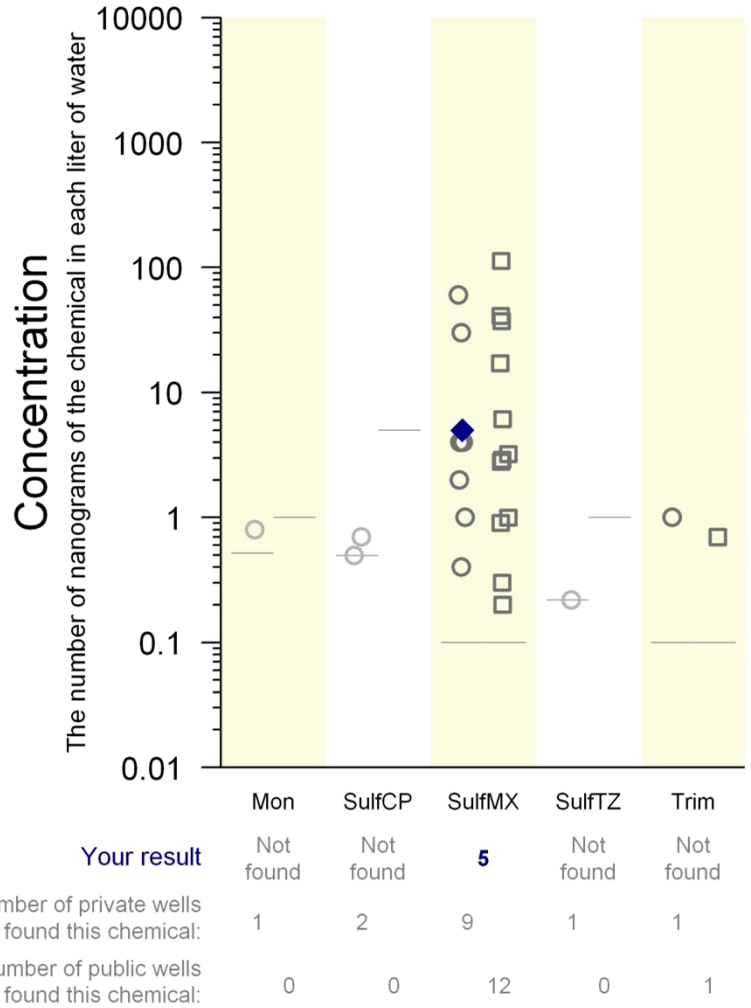
Pharmaceuticals in your water sample: Antibiotics

Did we find any antibiotics in your water sample?

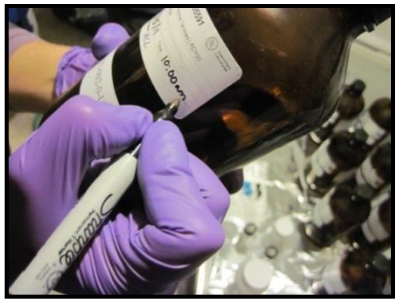
We found one antibiotic in your water sample, sulfamethoxazole (SulfMX). Information about this chemical is provided in Part 5.

There are no standards or guideline values for antibiotics in drinking water.

How to read this chart:	Your sample Other private wells in this study Public wells on Cape Cod Lowest level reportable by the lab



Summary



- OWCs detected in most public and private wells tested on Cape Cod
- Levels for several pharmaceuticals span the range detected in other US water supplies
- Nitrate, boron, and residential land use significantly correlated with OWC presence
- Well depth negatively correlated
- Artificial sweetener strongest predictor in private wells

Acknowledgements

- Ruthann Rudel, Janet Ackerman, Sarah Dunagan, Julia Brody
- Study volunteers and participating water supply districts
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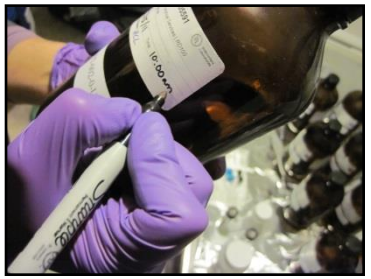
- Deborah Lee, Ali Criscitiello, Farley Lewis



website: www.silentspring.org/water

email: schaider@silentspring.org

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